Miljø- og Fødevareministeriet

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A Simple Model to Estimate Nitrogen Leaching from Catch Crop Residues depending on their Chemical Composition

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Introduction

This report describes the link of the Burns leaching equation with the previous developed model for predicting the amount and rate of mineral nitrogen (N) released from crop residues for: (i) estimating the fraction of N leached over the winter period, (ii) the fraction of N that remains in the soil after winter (April) for potential uptake by the subsequent main crop, and (iii) the fraction of N that is released during the growing period of the main crop.

It is assumed, that after the ploughing of the cover crop the residues will be uniformly distributed in the soil from the surface to a certain depth, z_o. Mineralization of the crop residue will release N, with the amount and rate depending on the temperature and characteristics of the crop residue, for which we here use the N concentration (N_{con}). The N release is given by:

$$AN(DD) = AN\left(1 - exp^{-k\,DD}\right) \quad (1)$$

where DD is the Degree Day, and AN and k were related to the N_{con} of the crop residue:

$$AN_1\,(\%) = a_1 + b_1\,(N_{conc}) \quad (2)$$

$$k_1 = c_1\,{N_{conc}}^{d_1} \quad (3)$$

The values for the parameters were found by fitting the equations to incubation experiments performed at 2 and 10^{o}C, and with crop residue N_{conc} ranging from 17 to 40 mg N/ g DM. For $N_{conc} \geq 24$ mg N/ g DM values are: a_1 = 1,35 and b_1 = 1,16, c_1 = 4,45 x 10-9; d_1 = 3,83. For $N_{conc} < 24$ mg N/ g DM immobilization was observed which was accounted for by a delay in the start of the mineralization of 210 DD.

The fraction (x) of N that is leached at a given depth z is according to Burns leaching equation given by (Scotter et al., 1993):

$$x = \frac{I}{\theta\, z_0}\left\{\exp\left[\frac{(z_0 - z)\,\theta}{I}\right] - exp\left(\frac{z\,\theta}{I}\right)\right\} \quad (4)$$

where θ is the soil moisture at field capacity (m3/m3), and I is the drainage (rainfall less evaporation)

Methods

The model was set up with:

- two different climate locations: Askow (wet climate with an average RF of 1087mm and T_{avg} of 8.5°C) and Flakkebjerg (dry climate with an average RF of 670 mm and T_{avg} of 8.7 °C)
- two different soil types (sand with a FC of 0,145 m^3/m^3, and loam with a field capacity of 0,3 m^3/m^3)
- two different residue incorporation times (1st November and 1st February)
- two different crop residue N concentrations, N_{con} of 24 and 40 mg/kg DM

The leaching model was set up on a monthly time step, and run for 20 different years to capture year-to-year variability in temperature and rainfall and its effect on the mineralization rate and the leaching.

For estimating the fraction of N that is leached from the crop residue, the amount of N mineralized (% of applied) was calculated on a monthly basis using equation 1, and the fraction of this amount leached was then calculated using equation 4. The drainage amount for the first month after residue incorporation was the total drainage until the 1st of April, whereas the next months had successively less drainage. The total amount (% of applied) was then the sum of leaching over the various months.

The amount of N mineralized over winter was, as expected, much lower for the crop residue with the low N_{conc} compared with the high N_{conc} (Figure 1). The N that can be mineralized during the 7 months period (AN) are 29 and 48%. At the high N_{conc} most of this AN got mineralized when the residue was incorporated in November. Incorporation in February reduced this to about 30% of the N applied. The climate had very little effect on N the mineralization, as the temperatures are very similar for the two locations.

Figure 2 shows the N mineralization over winter for the various years, which shows little variability when incorporation occurs in November. For the incorporation in February, however, there is a large variation for the residue with the high N_{conc}, due to the variability in temperature and the high sensitivity to this over the short mineralization duration of 2 months (February and March). As it was assumed that the soil type and the management history has no effect on N mineralization from the crop residue (see previous report), there are no differences between the two soil types in the amount of N released.

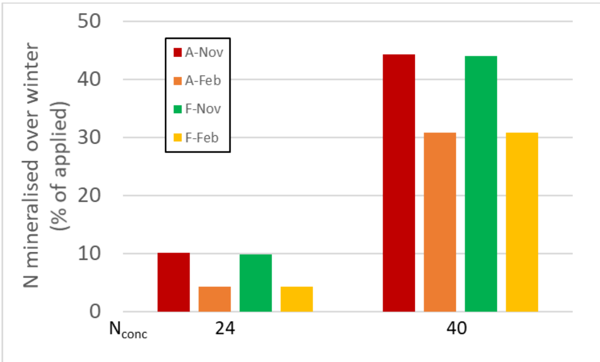

Figure 1. Amount of N mineralized to the 1st of April (% of applied) with A = Askov climate, and F = Flakkebjerg, and Incorporation in November or February and for two different crop residue N concentrations. Shown are averages over 20 years.

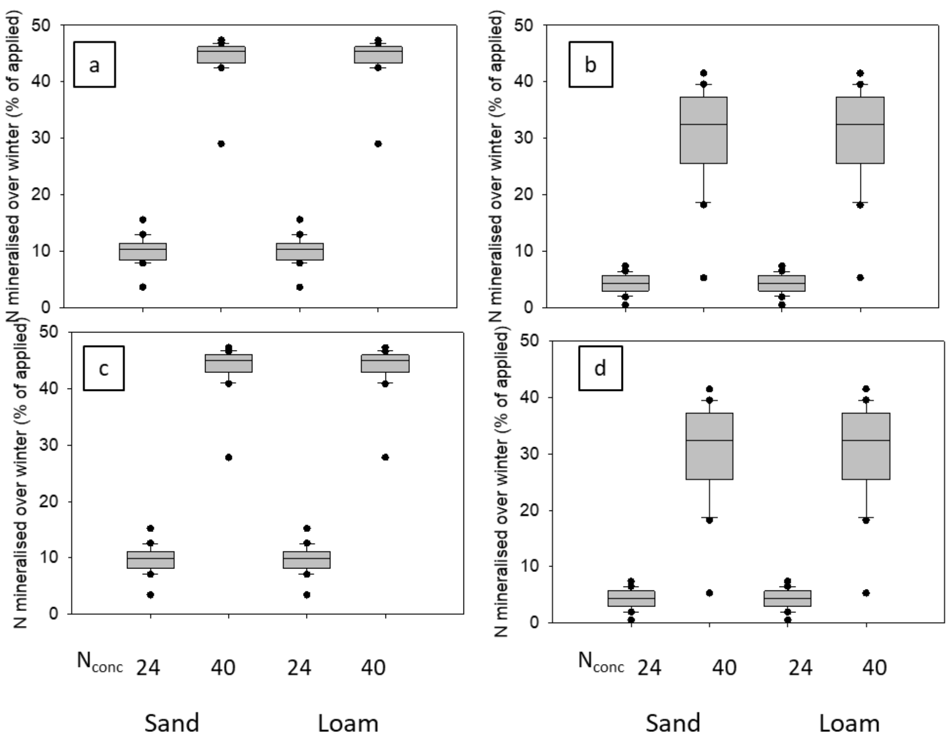

Figure 2. Amount of N mineralized to the 1st of April (% of applied) for a) Askov, Incorporation in November, b) Askov, Incorporation in February, c) Flakkebjerg, Incorporation in November, and d) Flakkebjerg, Incorporation in February for two different soil types and two different crop residue N concentrations.

The amount of the N leached over the winter period was dependent on the incorporation time, the N_{conc} and the soil type (Figure 3). Highest leaching with an average of 33% of the N applied occurred in the sandy soil under the Askov climate, with a high N_{conc} and incorporation of the residue in November. Leaching from the loam soil was also quite high with an average of 26%. Leaching was lower under the Flakkebjerg climate due to the lower rainfall over this period (on average 100 mm compared with 200 mm). Incorporation in February also substantially reduces N leaching. Crop residues with low Nconc showed little leaching, with the highest leaching of 6.5% occurring from the sandy soil under the Askov climate.

Similar to the N mineralized year-to-year variability in N leaching was highest for the incorporation in February with the high N_{conc} and under the Askov climate (Figure 4).

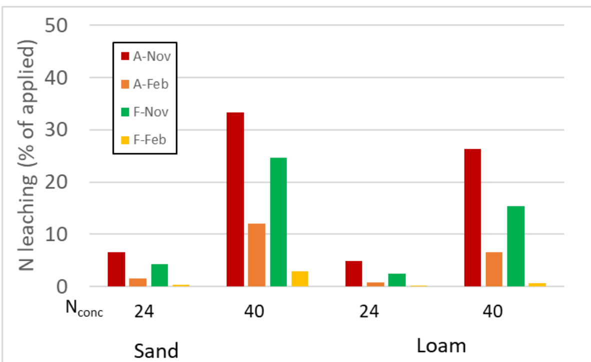

Figure 3. Amount of N leached to the 1st of April (% of applied) with A = Askov climate, and F = Flakkebjerg, and incorporation in November or February and for two different soil types and two different crop residue N concentrations. Shown are averages over 20 years.

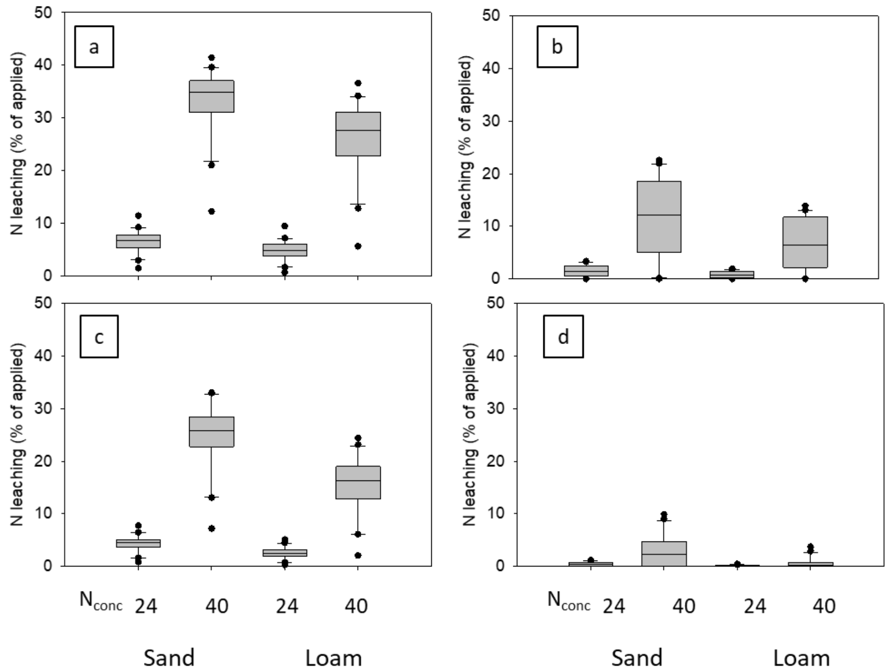

Figure 4. Amount of N leached (% of applied) for a) Askov, Incorporation in November, b) Askov, Incorporation in February, c) Flakkebjerg Incorporation in November, and d) Flakkebjerg Incorporation in February for two different soil types and two different crop residue N concentrations.

The N resident in the soil, which includes the N that has been mineralized over the winter, and the amount that is mineralizable in the short term is shown in Figure 5. Without any leaching these would equate to AN, which is 29% for the residue with an N_{conc} of 24 g/kg DM, and 48% of the one with an N_{conc} of 40 g/kg DM. Figure 6 shows that the N resident in the soil for the higher N_{conc} is highly dependent on environmental conditions, with a high year-to-year variability. In contrast, the low N_{conc} shows little variability over the years.

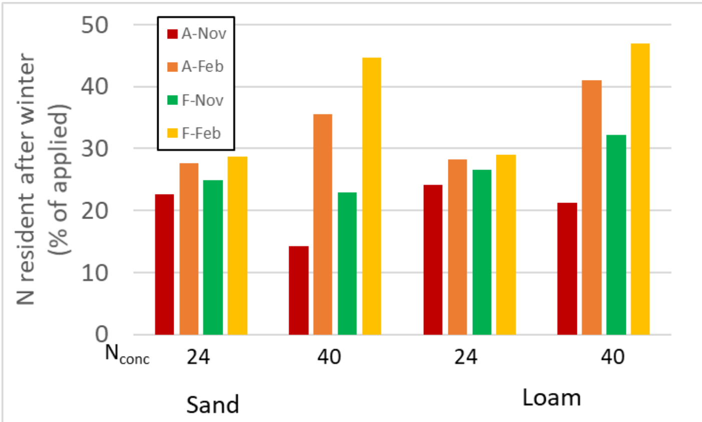

Figure 5. Amount of N resident in the soil on the 1st of April (% of applied) with A = Askov climate, and F = Flakkebjerg, and incorporation in November or February and for two different soil types and two different crop residue N concentrations. Shown are averages over 20 years.

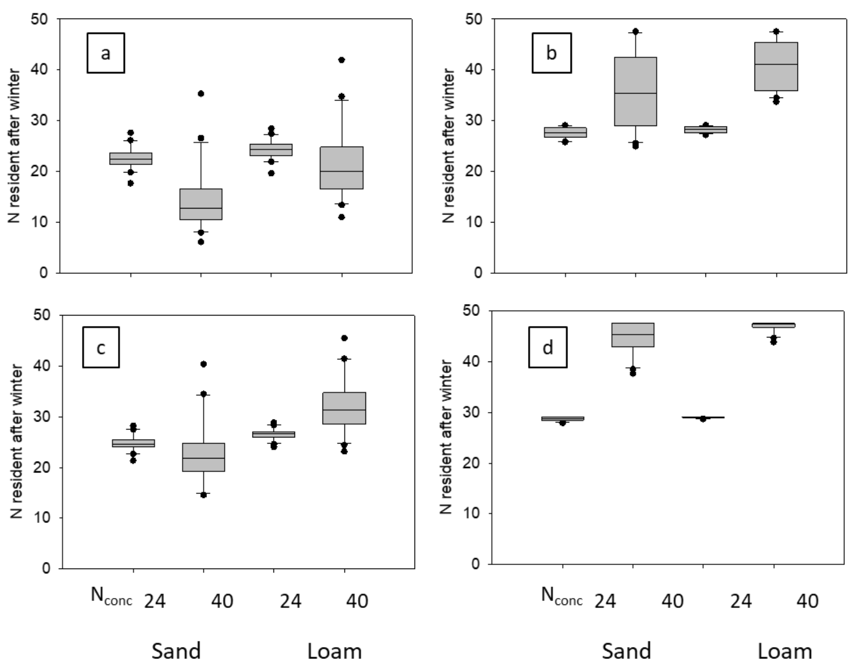

Figure 6. Amount of N resident in the soil on the 1st of April (% of applied) for a) Askov, Incorporation in November, b) Askov, Incorporation in February, c) Flakkebjerg Incorporation in November, and d) Flakkebjerg Incorporation in February for two different soil types and two different crop residue N concentrations.

The amount of N that can be mineralized over the growing period is, due to the slow release rate, much higher for the residues with a high N_{conc} (Figure 7). Note that in this simple calculation other factors that might limit mineralization (such as the soil moisture content) were ignored here. For the incorporation in November and the high N_{conc} there is very little N mineralization over the growing period, as most of the AN was mineralized over winter (Figure 1). The amount that can be mineralized during the growing period from the incorporation in February is still substantial with an average of 17%. However this is, in line with the amount mineralized over winter (Figure 2) highly variable over the years (Figure 8).

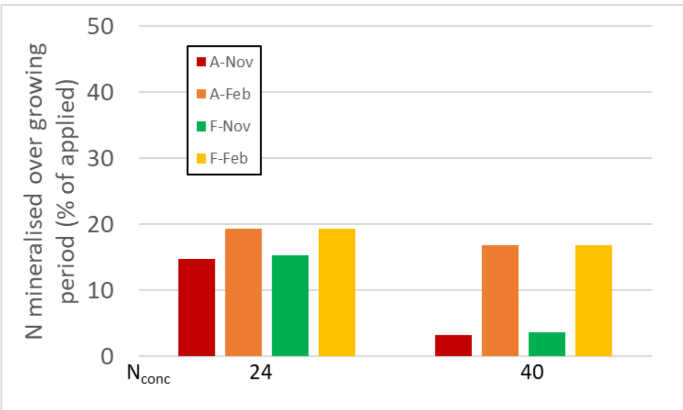

Figure 7. Amount of N that can be mineralized throughout the growing season (% of applied) with A = Askov climate, and F = Flakkebjerg, and incorporation in November or February and for two different soil types and two different crop residue N concentrations. Shown are averages over 20 years.

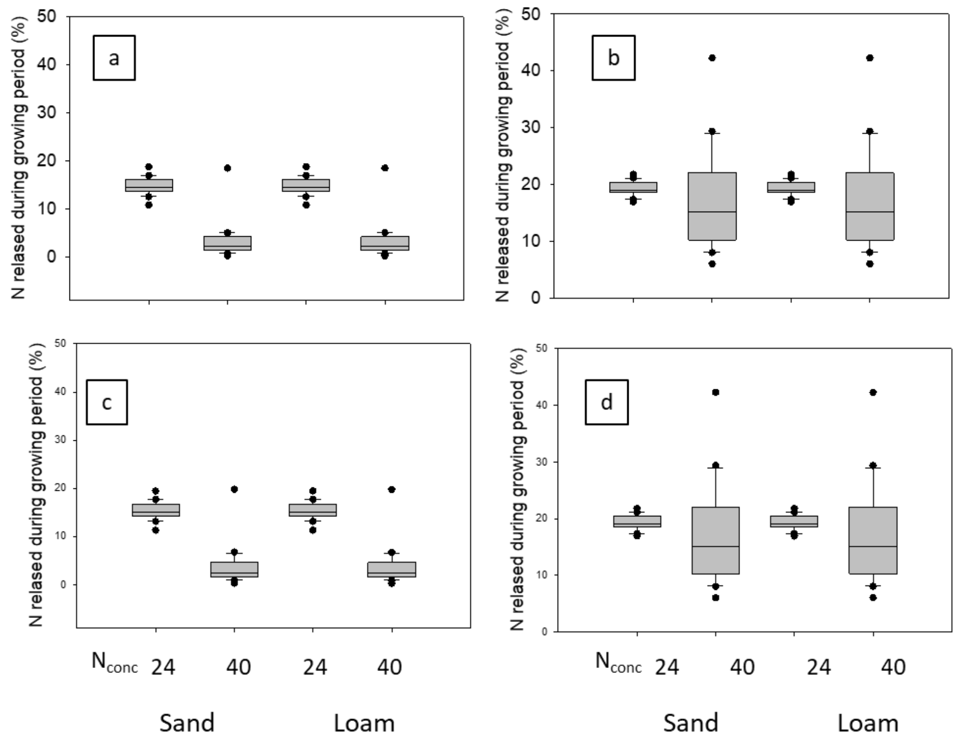

Figure 8. Amount of N mineralized from April to (% of applied) for a) Askov, Incorporation in November, b) Askov, Incorporation in February, c) Flakkebjerg Incorporation in November, and d) Flakkebjerg Incorporation in February for two different soil types and two different crop residue N concentrations.

References

Scotter, D. R., White, R. E., and Dyson, J. S. (1993). The Burns leaching equation. *Journal of Soil Science* **44**, 25-33.

Summary of Results

Table 1 provides a summary of the amount mineralized and leached (%) for the various scenarios modeled. The current modelling approach does not take into account the dynamics of soil moisture during the year, but rather assumes steady state (with the soil at field capacity), and also doesn't include any plant growth. As such some of the columns are left blank. Expert knowledge or a biophysical model, such as Daisy or APSIM, could be used to obtain estimates for these.

Table 1. Summary of the amount mineralized and leached

				Mineralised until 31 March	Leached before 1 April		Mineralised N remaining in soil 1 April		Mineralised N 1st April to 15 August	Total mineralised in winter and growing season to 15 August	Plant uptake			Remaining after growing season		
Climate	Incorporation time	Soil type	N conc	% of applied	% of mineralised	% of applied	% of mineralised before 1 April	% of applied	% of applied	% of applied	% of mineralised in growing season	% of mineralised during winter (non-leached)	% of applied	% of mineralised before 1 April	% of mineralised in growing season	% of applied
Askov	Nov	Sand	24	10,1	64,7	6,5	35,3	3,6	14,8	24,9						
Askov	Feb	Sand	24	4,3	35,0	1,5	65,0	2,8	19,3	23,6						
Flakkebjerg	Nov	Sand	24	9,8	43,7	4,3	56,3	5,5	15,2	25,0						
Flakkebjerg	Feb	Sand	24	4,3	9,2	0,4	90,8	3,9	19,3	23,6						
Askov	Nov	Sand	40	44,3	75,1	33,3	24,9	11,0	3,3	47,6						
Askov	Feb	Sand	40	30,8	39,0	12,0	61,0	18,8	16,8	47,6						
Flakkebjerg	Nov	Sand	40	43,9	56,1	24,7	43,9	19,3	3,7	47,6						
Flakkebjerg	Feb	Sand	40	30,8	9,5	2,9	90,5	27,8	16,8	47,6						
Askov	Nov	Loam	24	10,1	48,4	4,9	51,6	5,2	14,8	24,9						
Askov	Feb	Loam	24	4,3	18,5	0,8	81,5	3,5	19,3	23,6						
Flakkebjerg	Nov	Loam	24	9,8	25,5	2,5	74,5	7,3	15,2	25,0						
Flakkebjerg	Feb	Loam	24	4,3	2,0	0,1	98,0	4,2	19,3	23,6						
Askov	Nov	Loam	40	44,3	59,4	26,3	40,6	18,0	3,2	47,6						
Askov	Feb	Loam	40	30,8	21,4	6,6	78,6	24,2	16,8	47,6						
Flakkebjerg	Nov	Loam	40	43,9	34,9	15,3	65,1	28,6	3,7	47,6						
Flakkebjerg	Feb	Loam	40	30,8	1,9	0,6	98,1	30,2	16,8	47,6						